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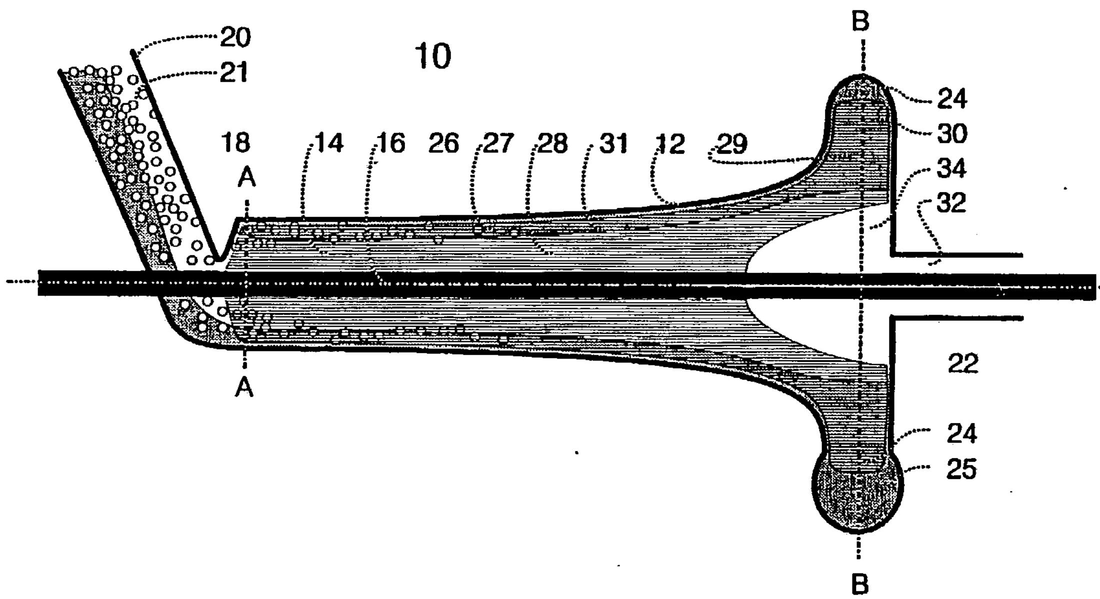

(57) Abstract

The invention relates to a gas separation pump and to a process for separating gas from a liquid when pumping the same. The pump (10) has a hollow shell, forming a separation part (26) with a large separation surface and a smoothly connected pump chamber (30), and a rotor with vanes (14) closely following the separation surface. The liquid-gas mixture flows along the large gas separation surface of the shell (12), whereby the gas essentially totally separates from the liquid and is discharged from the center of the pump chamber. The invention is particularly advantageous for air free recycling of paper machine backwater and for handling the products of flotation processes.

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Apparatus and process for pumping and separating a mixture of gas and liquid

The present invention relates to an apparatus and a process for separating a gas such as air from a low viscosity liquid such as water in connection with pumping a mixture of said gas and liquid. The invention also relates to the use of the apparatus for pumping backwater draining through a forming fabric of a paper machine and for pumping fluid material separated by flotation.

In many cases gas enclosed or generated in a fluid to be pumped causes problems. For example, when pumping fluids containing gas with a conventional centrifugal pump, the gas disturbs the pumping. The gas separating from the fluid under the influence of the centrifugal forces in the pumping chamber forms a gradually growing gas bubble, which decreases the power of the pump until the bubble finally is discharged. In processes requiring a constant flow such irregular function causes great disturbances.

As an example the backwater draining through the forming fabric in a papermaking process, normally, contains a large amount of enclosed air. Since the short circulation of a paper machine requires a particularly constant flow, the disturbing air is normally removed by conducting the drained backwater, by means of special pipe or channel systems, from the dewatering box or boxes to an open backwater tank, from where it is pumped back to the fibre process of the short circulation preceding sheet forming.

Air contained in the thin stock of the papermaking process also disturbs the stability of flow in the short circulation and disturbs the forming of the paper sheet by causing voids or holes in the sheet and by retarding the drainage of water. For the above reasons it is particularly important for the paper forming process to have an efficient deaeration of the drained backwater. Consequently, the backwater tanks and other parts of the system are traditionally designed for very low flow speeds in order to provide sufficient time for the enclosed air to emerge and be removed before the backwater is pumped into the closed part of the short circulation.

Due to the slow flow speeds, the recycling of backwater into the fibre process takes a significantly extended time, which in turn retards the reaching of a new equilibrium state after process changes, such as a change of the paper

grade. In addition thereto the slow flow speeds cause dirt buildup in tanks and pipings due to deposit therein of dispersed material and because of biological activity.

In cases where flotation is used for separating materials, such as in connection with de-inking of recycled wastepaper or the recovery of fibres from the long circulation in a paper machine, air separation, defoaming and pumping are particularly difficult and mostly require separate defoaming or settling tanks.

Pumps, which are able to separate gas from a fluid to be pumped are well known as such, but the objective of such pumps is normally just to remove a sufficient portion of the gas to enable regular pumping. The known pumps are normally not capable of removing enough gas for achieving the degree of freedom of air, which is required for using the fluid directly for example in a papermaking process without further deaeration. Deaerating pumps have also been designed for the treatment of fibre suspensions with a rather high solids content and having a high viscosity. In such pumps the separation of gas is generally caused by high shear forces in the highly viscous fluid which is to be pumped.

Examples of prior art pumps with which fluids which contain gas can be pumped uniformly are disclosed in FI 67591, US 4,410,337, US 5,039,320, FI 73023, FI 75912, which all are so called MC-pumps developed for pumping high consistency (about 5% to 20%) pulp, which must be fluidized in the suction channel of the pump, whereby air is separated through shear and centrifugal forces. The separated air concentrates in the center of the pump and is discharged by various means. Due to the small separation volume and high viscosity of the fluids to be pumped the separation of liquid and gas is not complete in the prior art pumps mentioned above. Consequently, separation of solid material and liquid from the discharged air is further required as taught for instance in Patent Applications EP 337394 and EP 298442.

International Patent Application published as WO 92/03613 discloses a stock feeding arrangement and process wherein a fibre suspension is pumped by means of "modified" versions of the MC-pumps mentioned above. However, the specification does not explain how these pumps are to be modified.

Other means for separating gas from fluids, or for pumping fluids containing or developing vapor are disclosed in Patents such as US 2,575,568, US

3,203,354, US 3,323,465, US 3,856,483, US 4,201,555, US 3,942,961, US 4,600,413, US 4,908,048 and EP 430636.

The object of the present invention is to improve the function of known processes and apparatuses in order to provide an essentially complete separation of gas from a liquid of relatively low viscosity such as water.

The object of the invention is also to provide the liquid to be pumped essentially free of gas and the gas essentially free of liquid.

The process and the apparatus according to the invention are particularly well suited for fast and controlled recycling of backwater drained at the forming of a paper or board web back into the short circulation fibre process, whereby the degassed backwater can be recycled without separate deaeration.

The object of the invention is to provide a technically simple pump which can remove gas such as air essentially totally from a low viscosity liquid such as water and separate the liquid essentially completely from the removed gas.

The object of the invention is further to provide a pump which does not influence the incoming flow of liquid to the pump and which is substantially self adjusting according to the incoming flow within a function range.

The object is further to provide a self adjusting gas separating pump, the function range of which can easily be adjusted by adjusting its speed of rotation.

The object of the invention is further to provide a gas separating pump, which can be connected to a vacuum source, and particularly so that the pump can be connected between the vacuum source and the suction object.

The object of the invention is also to provide a means for extinguishing foam and to pump foaming liquid while separating gas from said the liquid.

The object of the invention is further to provide a process for separating gas in combination with pumping.

Particularly the object of the invention is to enable fast and controlled recycling of backwater from a paper or board forming process to the fibre process.

Further the object of the invention is to enable air separation and controlled processing of fluid material separated by flotation.

The present invention thus relates to an apparatus for pumping a mixture of a gas such as air and a low viscosity liquid such as water and for separating said gas and said liquid from each other. Said apparatus comprises a hollow shell of a circular cross-section having at one end thereof an inlet for said mixture and at the opposite end an outlet for separated liquid. Said apparatus further comprises a rotor having vanes for causing said mixture to rotate and a gas outlet extending into a gas column formed in the center of said pump chamber. According to the unique features of said apparatus said shell consists essentially of a gas separation part at said inlet end and a larger diameter pump chamber at said outlet end, the inner wall of said gas separation part comprising a large gas separation surface for the essentially complete separation of said gas from said mixture, and said vanes of said rotor have essentially the same configuration as said gas separation surface and extend close to said surface.

Said shell of said apparatus has an elongated centrifugal separation part providing said large gas separation surface. Said separation part is smoothly connected to said larger diameter centrifugal pump chamber. Said vanes of said rotor are preferably cut away at the center of said pump chamber so as to leave an open space defining a vortex chamber for the gas.

In a preferred embodiment of the invention a vacuum source connected to said gas outlet provides means for the suction of gas from the apparatus. The vacuum source can simultaneously act as a vacuum source for the forming zone of a paper machine, said vacuum being applied through the apparatus.

In another preferred embodiment, nozzles are provided in the rotor shaft and/or at the outlet end of the shell, for spraying fluid into said open vortex so that foam generated or supplied to the gas separation surface will be extinguished through the action of the sprays.

The present invention also relates to a process for separating a liquid of low viscosity such as water or the like aqueous liquid from a relatively lighter gas such as air, and pumping the liquid separately from said gas.

The steps of said process comprise bringing said mixture into rotation in a gas separation part of a gas separation pump having a circular cross-section for

causing said mixture to flow towards a large gas separation surface formed by a wall of said gas separation part; causing said rotating mixture to flow along said gas separation surface in an essentially laminar flow in a thin fluid layer on said gas separation surface and causing said gas to separate from said liquid due to said rotation of said mixture to form a gas column at the center of said gas separation part; causing said separated liquid to flow along said gas separation surface into a larger diameter pump chamber connected to said gas separation part while continuing said rotation, thus causing said liquid to form a liquid ring at the periphery of said pump chamber; and discharging said liquid from said periphery of said pump chamber and discharging said gas from said gas column at the center of said pump chamber or said gas separation part.

In a preferred embodiment of the invention the gas is discharged by means of vacuum applied to said central gas column through said gas outlet. Due to the central gas column vacuum applied to said outlet also causes vacuum in the inlet pipe of the pump. Applied vacuum also causes the gas bubbles enclosed in the liquid to expand which further facilitates the separation of gas and liquid.

In another preferred embodiment of the invention foam floating on the separation surface is extinguished by spraying fluid into the central gas column.

The invention, together with additional objects and advantages thereof will be best understood from the following description, when read in connection with the accompanying drawings, of which:

Fig. 1 shows a section of a gas separation pump according to a preferred embodiment of the invention seen from the side. This Figure also shows the liquid and gas flowing in the pump;

Fig. 2 shows a section of the gas separation pump of Fig. 1 along line A-A;

Fig. 3 shows a section of the gas separation pump of Fig. 1 along line B-B;

Figs. 4 and 5 show sections of gas separation pumps according to other embodiments of the invention seen from the side;

Fig. 6 shows a section of the gas separation pump of Fig. 4 along line C-C;

Fig. 7 shows a section of a gas separation pump according to a favorable embodiment with foam extinction nozzles of the invention seen from the side;

Figs. 8 and 9 show the use of gas separation pumps according to the invention in papermaking processes;

Fig. 10 shows the use of a gas separation pump according to the invention in connection with a compact flotation device.

In the preferred embodiment of the invention according to Fig 1 the gas separation pump indicated by a general reference 10 comprises a hollow shell 12 having a circular cross-section and in said shell a rotor 16 having vanes 14 which essentially follow the shape of the inner surface of said shell 12. At the inlet end 18 of said shell 12 there is an inlet pipe 20 for the gas and liquid mixture, and at outlet end 22 there is a liquid outlet 24 and liquid discharge pipe 25.

Said shell 12 at said inlet end 18 forms an elongated gas separation part 26, the wall of which provides a large separation surface. The gas separation part shall, according to the invention be sufficiently long, for allowing sufficient time and space for the liquid fed through inlet 20 and possible sprays resulting from the action of rotor 16 in the inlet end of the apparatus, to settle at said separation surface and for any gas enclosed during this settling to separate. In order to provide this time and to obtain a favourable ratio between tangential flow speed at said separation surface and the centrifugal force causing the separation, the diameter of separation part 26 should be relatively small compared to the length of said separation part 26. Thus the separation part 26 should have a diameter which is smaller than its length, preferably smaller than half of its length.

The gas separation surface shall, according to the invention, be sufficiently large for letting the gas separate from the liquid when the mixture flows through said separation part. During use a thin fluid layer 27 of the mixture forms on the surfaces of the separation part 26. In the thin layer the distance for the gas to reach the surface 31 of the mixture is short. In the center of said shell 12 the separated gas forms a gas column 28 surrounded by the mixture layer 27. Said layer 27 gradually releases all contained gas and transforms into a gas free liquid layer.

The present invention is mainly designed to be used only for liquids of a relatively low viscosity which flow easily along a surface. No excessive shearing forces are applied to the liquid-gas mixture by the pump. On the contrary a laminar flow of liquid is desired so as to avoid mixing gas into the liquid.

Due to the rotation of said rotor 16 the fluid layer 27 is caused to rotate rapidly in said shell 12 and is subject to a centrifugal force, which causes the enclosed gas bubbles in the mixture to raise rapidly to the surface of the mixture and from there towards the center of the gas separation pump forming gas column 28. In the separation part 26 the vanes 14 of rotor 16 must extend so closely to the inner surface of said shell 12 that the fluid layer 27 is not disrupted through the force of the vanes 14 but retains an essentially laminar flow. In order to avoid uncontrolled turbulence and sprays at said inlet 18 of the separation part, said vanes 14 are at this point preferably shaped in a spiral form which follows the natural flow path of the mixture when accelerating.

At said outlet end 22 aid shell 12 enlarges smoothly into a pump chamber 30. During use of the apparatus the liquid forms a deeper liquid ring 29 in said pump chamber 30 which causes the accumulating pressure at the periphery of the pump chamber 30 to increase and the liquid, now essentially free of gas, to be discharged via liquid outlet 24 through liquid discharge pipe 25.

If the flow, pumped through discharge 25 is smaller than the flow arriving through inlet 20, this causes the depth of water ring 29 and thus also of the pumping pressure and consequently the outlet flow to increase. The gas separation pump according to the invention is thus self adjusting within certain limits. The pressure of the pumped liquid can also be adjusted by adjusting the rotation speed of the rotor 16, and thus the range of self adjustment can be set to meet prevailing operating conditions.

In the embodiment according to Fig 1 the separation part 26 smoothly transforms into the pumping chamber 30 without any distinct transition point. Thus the most preferred embodiment of the invention is obtained, where the shell 12 enlarges like a funnel and smoothly from a separation part to a pump chamber. Thanks to the smooth construction the liquid layer 27 can flow without disruption from separation part 26 to pump chamber 30. A violent transition might cause a disruption of the laminar flow and cause gas to mix into the liquid already freed from gas.

In order to avoid violent acceleration at the transition area between separation part and pump chamber, where the gas column might enlarge, it is favorable to let the vanes 14 follow a spiral path at this point.

Even if the funnel-like conical shape of shell 12 represented by Fig 1 is considered the most preferred embodiment of the invention, the geometrical shape of the separation part 26 is not limited to this form. The invention functions also if the separation part is shaped like a cone or has an intermediary shape.

In order to provide a large and stable gas column 28 in said gas separation part 26, and also a large surface 31 of fluid layer 27, permitting an efficient gas separation, the gas column should occupy a significant portion, preferably not less than half of the available volume of the gas separation part 26 of shell 12. Hereby the fluid layer 27 will remain relatively thin, preferably less than one sixth of the diameter of the gas separation part, whereby the centrifugal forces cause only a modest pressure build up in said fluid layer, and excessive compression of the gas bubbles enclosed in said fluid layer is avoided.

In order to have a thin fluid layer in separation part 26 and still obtain a desired pumping pressure in pump chamber 30, the diameter of the pump chamber 30 is favorably significantly larger than that of gas separation part 26.

In order to maintain a smooth laminar flow throughout the apparatus and for avoiding disruptions in the laminar flow of fluid layer 27, the space between vanes 14 and shell 12 must be small compared to the thickness of fluid layer 27. The space between said vanes 14 and said separation surface should thus be less than 1/10 of said diameter of said gas separation part 26 and preferably about 1/20 to about 1/60 of said diameter.

The vanes 14 of rotor 16 therefore preferably increase in diameter in the same way as the shell 12, following closely the inner surface of the shell all the way from the separation part 26 to the pump chamber 30.

In the described embodiment, the rotor 16 is driven by a shaft, which extends through both ends of the shell 12, but in other embodiments, the shaft may be arranged to go through only one of the two ends. In either case the vanes are preferably shaped so that in the center of the pumping chamber 30 at the outlet end 22 remains a central space without vanes constituting a vortex

chamber 34.

At the outlet end 22 of the shell 12 there is a gas outlet 32 through which the gas accumulating in the gas column 28 is removed. The gas is always removed from the gas column 28 and preferably from vortex chamber 34, where the liquid has essentially totally been separated from the gas. The gas outlet may alternatively be arranged centrally or decentrally through the outlet end 22 of the shell 12 or through a tubular shaft of rotor 16 through either end of the shell 12.

In a preferred embodiment of the invention gas outlet 32 is connected to a vacuum source (not shown), so that the gas cumulating in gas column 28 may be removed by suction. The vacuum causes the gas bubbles enclosed in the fluid layer 27 to expand, thus increasing their flow speed towards the liquid surface 31 and into gas column 28. If the applied vacuum is deep enough, it causes the liquid in fluid layer 27 to boil, whereby also dissolved gas is liberated and removed from the liquid.

The advantages of the gas separation pump 10 according to the present invention will be especially evident when said pump is used in a paper making process and the vacuum needed for drainage at the papermaking machine forming fabric is caused by suction through the gas outlet 32 of the pump. The vacuum at the forming fabric can be applied either through the inlet pipe 20 or through a separate suction pipe (not shown) connected to the inlet end 18 of pump 10.

A stable flow of backwater to the pump 10 may be provided either by feeding the drained backwater to said pump 10 through an inlet pipe so spacious that the backwater surface always remains open, or by keeping the inlet pipe constantly full of water when applying the vacuum at the forming fabric through said separate suction pipe.

Figure 2 shows a section A-A of the pump 10 of Fig. 1, which shows the preferred tangential junction of inlet 20 to the inlet end 18 of shell 12. Due to the tangential feeding the mixture of gas and liquid has an initial spiral motion. The mixture can also be fed into the pump 10 through multiple, preferably circularly arranged inlet pipes (not shown). As seen in Fig 2 the vanes 14 of rotor 16 extend close to the inner surface of shell 12. The vanes 14 are formed in a spiral shape in order to allow a smooth acceleration of the liquid, avoiding

excessive turbulence.

It is also seen that the gas column 28 continues as a void space 21 in the spacious inlet pipe 20 so that the gas pressure in the gas column 28 and the inlet pipe 20 are the same, and the liquid can freely flow into the shell 12 forming a relatively thin fluid layer 27 on the inner surface of shell 12 by influence of the centrifugal force caused by vanes 14.

Fig 3 represents the section B-B, at the outlet end of the pump 10 of Fig 1. Fig 3 shows the pump chamber 30 with its larger diameter, the outlet 24 which extends in a spiral form around the pump chamber 30 and the liquid ring 29 formed during use in the pump chamber. In the center of the pump chamber 30 the inner diameter of the liquid ring 29 varies according to the operating conditions, changing the shape and diameter of the inner surface 31 of fluid layer 27.

Fig 4 shows another embodiment of the present invention. The reference numbers used in Fig 4 correspond to those presented in Fig 1. In this embodiment, which functions essentially in the same way as the embodiment of Fig 1, the shaft of rotor 16 passes only through the inlet end 18 of shell 12. In this embodiment the inlet 20 is shaped as a spiral, permitting a smooth and symmetrical distribution of the inlet flow to the fluid layer 27 of separation part 26.

Fig 5 shows an other embodiment of the present invention. The reference numbers used in Fig 5 correspond to the parts presented in Fig 1. The gas outlet 32' is in this embodiment incorporated into the shaft of the rotor 16, and said shaft goes through only the inlet end 18 of shell 12. Correspondingly there may be other arrangements of the rotor shaft and gas outlet which are obvious to those skilled in the art and which do not alter the overall function of the apparatus.

As seen in Fig 6, representing a section of the pump of Fig 5 along line C-C, although drawn in smaller scale, the number of vanes 14 in the pump chamber 30 can be larger than that in the separation part 26, additional winglets 36 are provided in order to improve the circulation of the liquid in the liquid ring (not shown) and decrease pressure pulsations at the liquid discharge 25. The winglets 36 are fixed to the rotor 16 in any known manner (not shown).

Fig 7 represents a preferred embodiment of the apparatus for separating gas and pumping the essentially gas free liquid when the fluid mixture is a foam or strongly tends to form foam. The apparatus is in other respects essentially similar to the embodiment of Fig 1 but it further comprises feeding pipes 40 for spraying fluid into gas column 28 through nozzles 41 arranged in the outlet end of shell 12. The pipes 40 and nozzles 41 are preferably adapted for spraying fluid into vortex chamber 34. In this embodiment the vortex chamber has been expanded in order to permit free access of sprayed fluid to a larger part of liquid surface 31. The vanes 14 have deflectors 43 turned towards nozzles 41. Further towards inlet end 18 of the apparatus other deflectors 44 are fixed on the rotor 16. The deflectors 43, 44 are designed so that they will be hit by a distinct fluid jet 42 from a nozzle 41, causing the jet to disintegrate into droplets 45 and directing these droplets towards the fluid surface 31 of fluid layer 27 on the inner wall of the shell 12.

Another type of nozzle is shown at 41A. This nozzle 41A is of a known type for direct spray of fluid droplets onto surface 31. Alternatively spray nozzles (not shown) may be incorporated into the rotor and fed through a duct in the rotor shaft in a way easily understood by those skilled in the art. A combination of different types of spray nozzles is contemplated within the scope of the present invention. Droplets 45 sprayed from the nozzles and hitting the surface 31 cause foam on this surface to collapse.

For the apparatus aspect of the present invention it is above all essential that a large gas separation surface is formed in the separation part 26 and that the rotor vanes 14 closely follow this surface so that a thin rotating liquid layer 27 can be formed on said surface. Gas separated by means of the centrifugal force is collected into a distinct gas column 28, from where it is removed. The large separation surface is provided by the elongated separation part 26 having a length substantially exceeding its diameter.

In a preferred application of the invention in a papermaking process it is further essential that suction needed for other purposes can be applied through the present apparatus. In said preferred embodiment foam will be extinguished by spraying fluid into the gas column.

According to the process of the present invention a mixture of gas and liquid is separated into an essentially gas-free liquid an essentially liquid-free gas. The liquid is a low viscosity liquid like water and the gas is air or another gas subs-

tantially lighter than the liquid component of the mixture. The liquid may contain minor amounts of fibers or other impurities such as ink particles which do not, however, make the fluid mixture viscous.

In the process the gas/liquid mixture is fed for instance into the gas separation pump 10 of Fig. 1 through inlet pipe 20. The mixture is brought into rotation by rotor 16 so that it is slung onto the gas separation surface formed on the inner surface of shell 12 in gas separation part 26. Thus a rotating liquid layer 27 is formed on said surface.

Due to the centrifugal force caused by the rotation, the lighter gas enclosed in the liquid strives out from the liquid towards the center of the apparatus forming a gas column 28. Correspondingly the heavier liquid droplets collect at the shell wall and form a liquid layer 27 on the gas separation surface. The enclosed gas will easily pass through the thin liquid layer, separate from the liquid and transfer into the gas column in the center of the apparatus.

The liquid flows continuously from the inlet end 18 towards the outlet end 22 along the separation surface of the separation part 26 reaching the pump chamber 30 which is smoothly connected to the separation part 26. The diameter of the shell 12 increases at the transition between separation part 26 and pump chamber 30, whereby the rotating, now essentially gas free liquid is pressed toward the periphery of the pumping chamber 30, forming a liquid ring 29. The liquid ring, due to centrifugal forces, is pressed into the liquid outlet 24, which extends as a spiral around the periphery of the pump chamber 30, and is discharged through the discharge pipe 25.

The lighter gas, correspondingly, collects into the center of the apparatus, and forms a gas column 28, limited towards the rotating fluid 27 by a surface 31. From this gas column 28 the gas can be removed and thus separated from the liquid. The gas is preferably removed from a vortex chamber 34 at the center of the pump chamber 30. The gas may be discharged either through a gas outlet 32 in the outlet end 22 of the shell 12 or through the rotor shaft in either outlet or inlet direction.

The depth of liquid ring 29 in pump chamber 30 automatically adjusts, within certain limits, to the flow of entering fluid so that a pumping pressure sufficient for pumping the liquid forward is obtained. The more fluid that enters the pump the deeper the liquid ring and the higher the pumping pressure. The

depth of the water ring as a function of the pressure difference can be adjusted by adjusting the rotation speed of the rotor. By adjusting the rotation speed the depth of the water ring can be adjusted according to the flow of incoming gas and liquid mixture and the required pumping pressure. Within certain limits the pump is self-adjusting. Without disturbing the process, the depth of the liquid ring in the pumping chamber can vary within a relatively large range, as long as the fluid layer 27 is not disrupted, no gas enters the liquid outlet 24 and no significant amount of liquid enters the gas outlet 32.

A suction source may be connected to the gas outlet 32 for improving the gas separation. Such use of a suction source is particularly preferred when suction is needed at the source of the mixture of gas and liquid. Due to the open gas column 28 formed in the center of the pump being in direct connection with a void space 21 in the inlet pipe 20, the suction applied at the gas outlet 32 will affect also equipment upstream of the pump 10. Particularly in the case when the mixture contains considerable amounts of gas, so that it rather consists of liquid droplets in an aerosol, the flow speed of the mixture can be increased by connecting suction to a pump according to the invention.

Foam flowing into the pump or forming in the same concentrates on the surface 31 of the fluid layer 27 and collapses rapidly due to the centrifugal forces, whereby the gas is liberated and strives towards the center. Particularly stable foam may be extinguished by directing sprays of a fluid, such as a liquid, towards the surface 31 of fluid layer 27. Spray nozzles are designed to spray the fluid within the void space of gas column 28, preferably through vortex chamber 34.

The gas separation pump according to the present invention is especially well suited for recycling paper machine backwater into the short circulation fibre process. Figs 8 and 9 represent a particularly favourable use of gas separation pumps in a process according to the co-pending patent application FI 922285, by the same inventor. It is obvious for the person skilled in the art that the present invention offers significant improvement also to conventional papermaking processes, by increasing recycling speed of backwater and eliminating the need for huge backwater tanks.

The solution according to Fig. 8 represents a papermaking process, where thin stock is fed through a head box 100 onto a forming wire, for the forming of a web. Backwater draining through the forming wire is collected in drainage

boxes 101, suction boxes 102 and the suction roll 103 and flows directly into gas separations pumps 10, 10' and 10", according to the present invention. The gas separation pumps 10' and 10" relating respectively to suction boxes and to a suction roll may be connected to a vacuum source (not shown) for providing the suction needed in said suction boxes and said suction roll.

The gas separating pumps 10, 10' and 10" separate the air contained in the backwater and feed the backwater as separate air free flows to various dilution points in the primary fibre process. Said fibre process goes from stock preparation 124 through a mixer 123, centrifugal cleaner 122, screen 121 and stock distributor 125 to the headbox 100 and further to paper web forming.

The solution according to Fig. 9 represents a papermaking process, wherein essentially the same reference numbering is used as in Fig. 8. In the process according to Fig. 9 the first part of web forming is made in a closed space and closed draining boxes are used for an air free recycling of backwater from the forming fabric to the fibre process. In the first, closed part of forming the backwater is thus recycled free of air by means of conventional centrifugal pumps 11, whereas backwater resulting from that part of the fabric where air will or can be pass through the fibre web is recycled by gas separation pumps 10 according to the present invention.

The gas separation pumps according to the present invention, thus provide means for fast and direct recycling of essentially air free backwater into the fibre process of a papermaking machine wet end.

In the process according to Fig. 8 a part of the collected backwater is fed to a fibre recovery unit 50 which is preferably designed according to co-pending patent application FI 930247 by the same inventor. In this fibre recovery unit, represented in detail in Fig. 10, fibres are separated from the backwater flow 61 by means of an air sparged hydrocyclone 51, forming a foam column 65 in the center of said hydrocyclone. Clear water, essentially free from solids is discharged through clear water discharge 63 and fed out from the short circulation. The foam from column 65 is extinguished in a foam extinguisher 52 by influence of white water fed into spray lines 62 and flows further into gas separation pump 53, which feeds the recovered stock 64, essentially free of air, directly into the fibre process.

The present invention, thus provides a means for separating air from the pro-

duct of such a compact flotation process, providing a means for the fast recycling of recovered fibres in the paper machine wet end. Similarly the gas separation pump according to the present invention provides a means for handling foam resulting from other flotation processes, like deinking of waste paper. Gas separation pumps for handling foam from flotation processes can favorably be of the type with integrated foam extinguishing, as represented by Fig. 7.

The present invention is further illustrated by the following Table, in which a small pump designed in accordance with the present invention runs with a flow of 10 and 20 liters per second, respectively (two first columns), and a bigger pump with a capacity of 200 liters per second. The Table shows the principal dimensions of a pump in millimeters, the rotation speed in revolutions per minute, the thickness of the liquid layer in the separation part in millimeters. The increase of the vortex between separation part and pump chamber in millimeters represents the step, i.e. the increase in radius of the gas column in the vortex chamber. These result in the g-force in the separation part and a nominal pumping pressure at the outlet of the pump. The equivalent separation surface represents an open surface, which would have the same gas separation capacity as the gas separation pump in the example. The equivalent flotation speed indicates the minimum separation speed in an open flotation basin for gas which is essentially totally separatable by a separation pump. Thus, for example, the pump of the first column would separate all gas having a flotation speed of 4.53 centimeters per minute or more in an open basin.

TABLE

Liquid flow (l/sec)	10	20	200	
Shell diameter, separation part (mm)		300	300	600
Pumping chamber diameter (mm)		600	600	800
Axial length, separation part (mm)		1000	1000	2000
Rotation speed, (rpm)		600	600	600
Liquid layer, separation part (mm)		20	30	50
Vortex increase at pump chamber (mm)		5	5	10
g-force, separation part (g)	15.08	15.08	30.15	
Pumping pressure, nominal (bar)		3.61	3.74	4.64
Equivalent separation surface (m^2)		13.25	12.78	104.14
Equivalent flotation speed (cm/min)		4.53	9.39	11.52

Similarly as for fibre recovery, flotation is used in other separation processes, as for example for the removing of ink particles from a fibre suspension resulting from pulping printed waste paper. In a deinking process the fibre suspension is typically 1 to 3 % such that a relatively stable fibre network results, whereas ink particles, which have been released from the fibres by mechanical and chemical means are mobile within the fibre network and are carried out from the suspension by gas bubbles transferring the same. The products of the deinking process are a foam containing ink particles and a suspension of deinked fibres. Both of these products contain a large amount of air and are difficult to process in prior art pumps.

The foam containing ink may preferably be handled by a gas separation pump according to the present invention in the same manner as the fibre material recovered according to the process described above.

The suspension of deinked fibres resulting from a deinking flotation process is typically saturated by air and the relatively stable fibre network traps the enclosed air bubbles and makes the handling thereof in gas separating pumps particularly difficult. When such a pulp suspension saturated by air trapped by a fibre network in handled in a pump according to the present invention, the separation of gas will be only partial, but due to the huge gas separation capability and smooth flow in the pump, the pumping will be very stable and the pump will function in a self regulating manner as explained above. By setting the pump under vacuum, the fibre suspension can also be brought to boil, whereby the enclosed bubbles expand and a total separation of gas is obtained.

The above example shows that even if the gas separation pump according to the present invention is primarily aimed at achieving an essentially total separation of gas and liquid when pumping a liquid, the pump will also provide great advantages in processes where prior art gas separation pumps are insufficient for pumping fluids wherein the gas is very hard to separate.

The present invention has been described principally as a pump solution relating to the paper industry. It is, however, obvious for the persons skilled in the art that the pump can be used for many other purposes when gas is to be removed from a liquid, and a liquid containing gas is to be pumped substantially free of gas.

Claims

1. An apparatus for pumping a mixture of a gas and a liquid and for separating said gas and said liquid from each other, said apparatus (10) comprising a hollow shell (12) of a circular cross-section having at one end (18) thereof an inlet (20) for said mixture and at the opposite end (22) an outlet (24) for separated liquid, said apparatus (10) further comprising a rotor (16) having vanes (14) for causing said mixture to rotate and a gas outlet (32) extending into a gas column (28) formed in the center of said pump chamber (30), said apparatus (10) being c h a r a c t e r i z e d in that said shell (12) consists essentially of a gas separation part (26) at said inlet end (18) and a larger diameter pump chamber (30) at said outlet end (22), the inner wall of said gas separation part (26) comprising a large gas separation surface for the essentially complete separation of said gas from said mixture, and in that said vanes (14) of said rotor (16) have essentially the same configuration as said gas separation surface and extend close to said surface.

2. An apparatus according to claim 1 wherein said gas separation part (26) is elongated having a diameter which is smaller than its length, preferably less than half its length.

3. An apparatus according to claim 2 wherein the space between said vanes (14) and said separation surface is less than 1/10 of said diameter of said gas separation part (26), preferably about 1/20 to about 1/60 of said diamter.

4. An apparatus according to claim 1 wherein said vanes (14) of said rotor (16) are shaped so as to leave an open vane-free central space at the center of said pump chamber (30) for forming a vortex chamber (34).

5. An apparatus according to claim 1 wherein the diameter of said gas separation part (26) smoothly increases to form said larger diameter pump chamber (30).

6. An apparatus according to any one of the preceding claims wherein said shell (12) is essentially shaped like a cone or a funnel.

7. An apparatus according to any one of the preceding claims wherein means (40, 41, 41A) are provided for spraying a fluid against said gas separation

surface.

8. An apparatus according to claim 7 wherein said spraying means are attached at said outlet end (22) of said shell (12) for spraying fluid into said vortex chamber (34).

9. An apparatus according to claim 7 or 8 wherein at least part of said spraying means comprise nozzles (41) attached to said outlet end (22) of said shell (12) and spray deflectors (43; 44) provided at said vanes (14) and/or at the shaft of said rotor (16).

10. An apparatus according to any one of the preceding claims wherein a vacuum source is connected to said gas outlet (32).

11. A process for pumping a mixture of a gas and a liquid so that said gas and said liquid separate from each other, c h a r a c t e r i z e d by

bringing said mixture into rotation in a gas separation part of a gas separation pump having a circular cross-section for causing said mixture to flow towards a large gas separation surface formed by a wall of said gas separation part,

causing said rotating mixture to flow along said gas separation surface in an essentially laminar flow in a thin fluid layer on said gas separation surface and causing said gas to separate from said liquid due to said rotation of said mixture to form a gas column at the center of said gas separation part,

causing said separated liquid to flow along said gas separation surface into a larger diameter pump chamber connected to said gas separation part while continuing said rotation, thus causing said liquid to form a liquid ring at the periphery of said pump chamber, and

discharging said liquid from said periphery of said pump chamber and discharging said gas from said gas column at the center of said pump chamber or said gas separation part.

12. A process according to claim 11 wherein said mixture comprises essentially a mixture of air and water which are substantially completely separated from each other.

13. A process according to claim 11 or 12 wherein said mixture is made to flow on said gas separation surface to form a fluid layer having a thickness which is less than one sixth of the diameter of said gas separation part.

14. A process according to claim 11 wherein said gas is discharged from a vortex formed in said center of said pump chamber.

15. A process according to claim 11 wherein said gas is discharged from said gas column by means of suction.

16. A process according to claim 11 or 12 wherein the depth of said liquid ring is adjusted by means of adjusting the speed of rotation.

17. A proces according to claim 11 wherein a spray of fluid is injected towards said layer on said gas separation surface.

18. In a process for producing paper or board the improvemnt comprising recycling backwater from a former in a papermaking machine into the fibre process with the aid of a gas separation pump according to any one of the preceding claims 1 to 10.

19. In a flotation process the improvement comprising treating a fluid flotation product in a gas separation pump according to any one of the preceding claims 1 to 10.

20. A process according to claim 19 wherein said floation process comprises recycling fibres from a fibre recovery unit into the fibre process of a papermaking machine.

21. A process according to claim 19 wherein said flotation product comprises a suspension resulting from deinking recycling paper.

22. A process according to any one of the preceding claims 18 to 21 wherein vacuum required at an upstream position relative to said gas separation pump is applied through said gas separation pump.

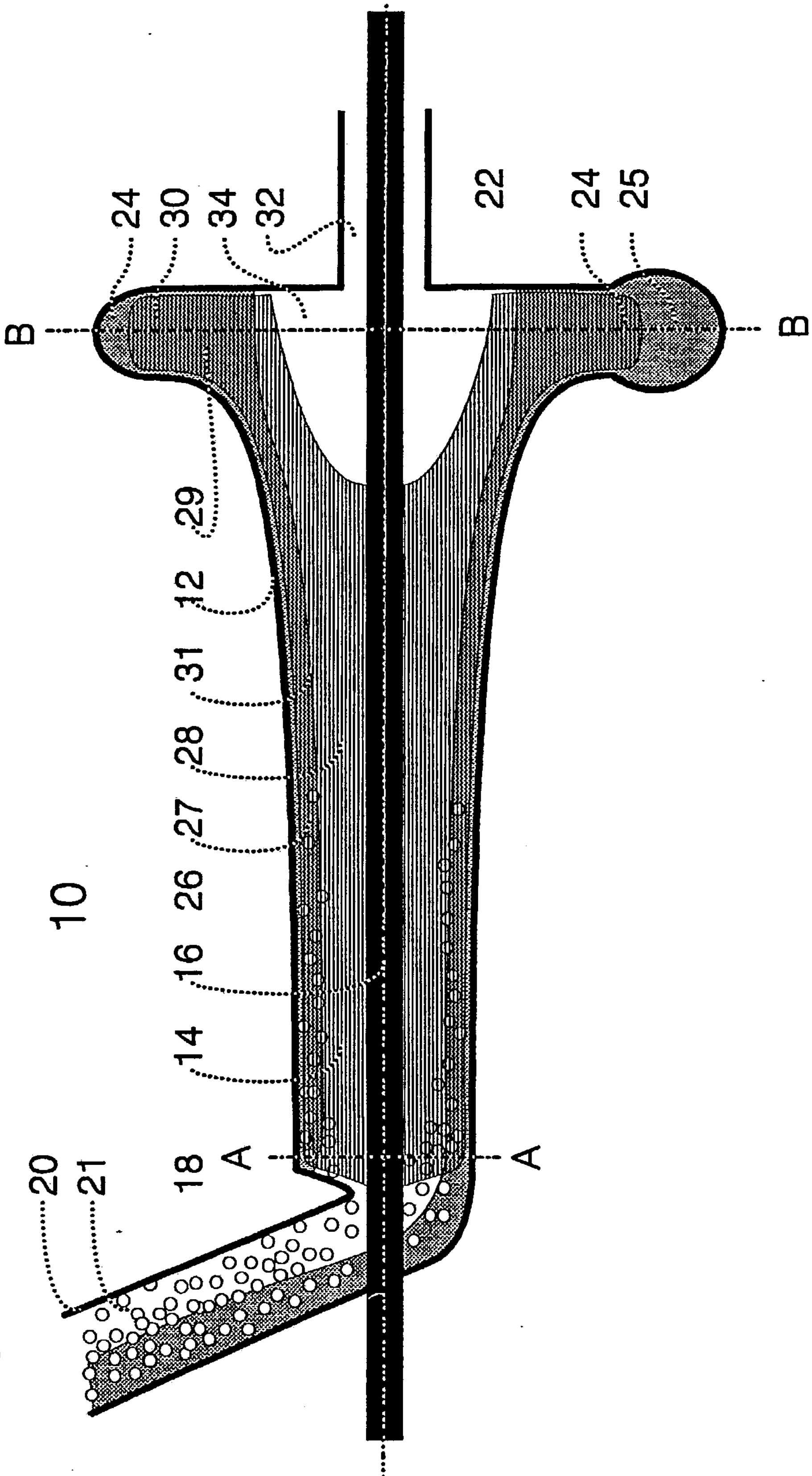


Fig 1

Fig 2

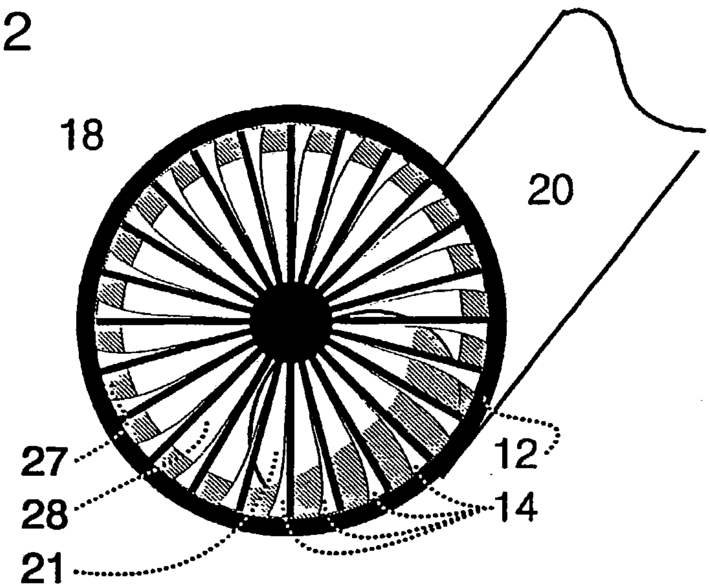


Fig 3

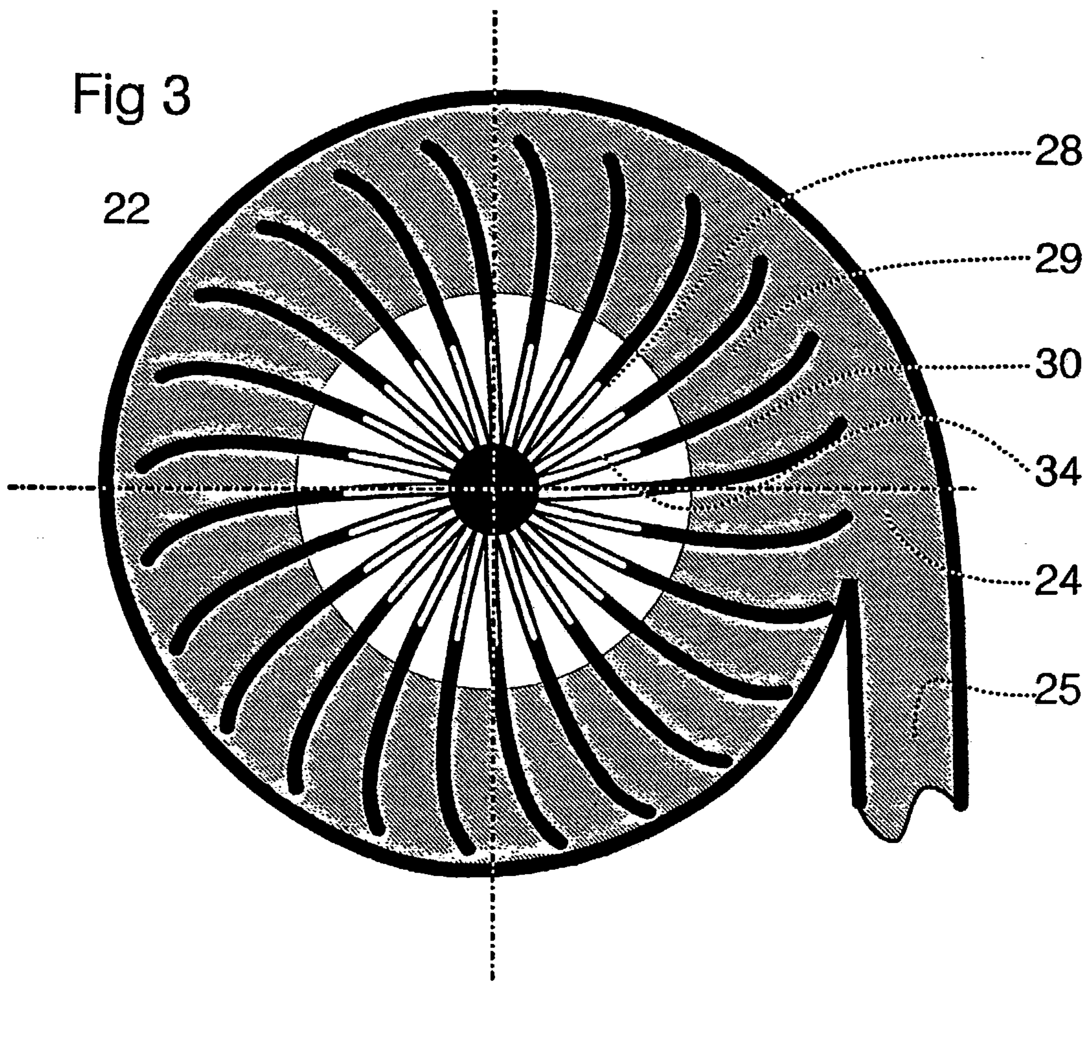


Fig 4

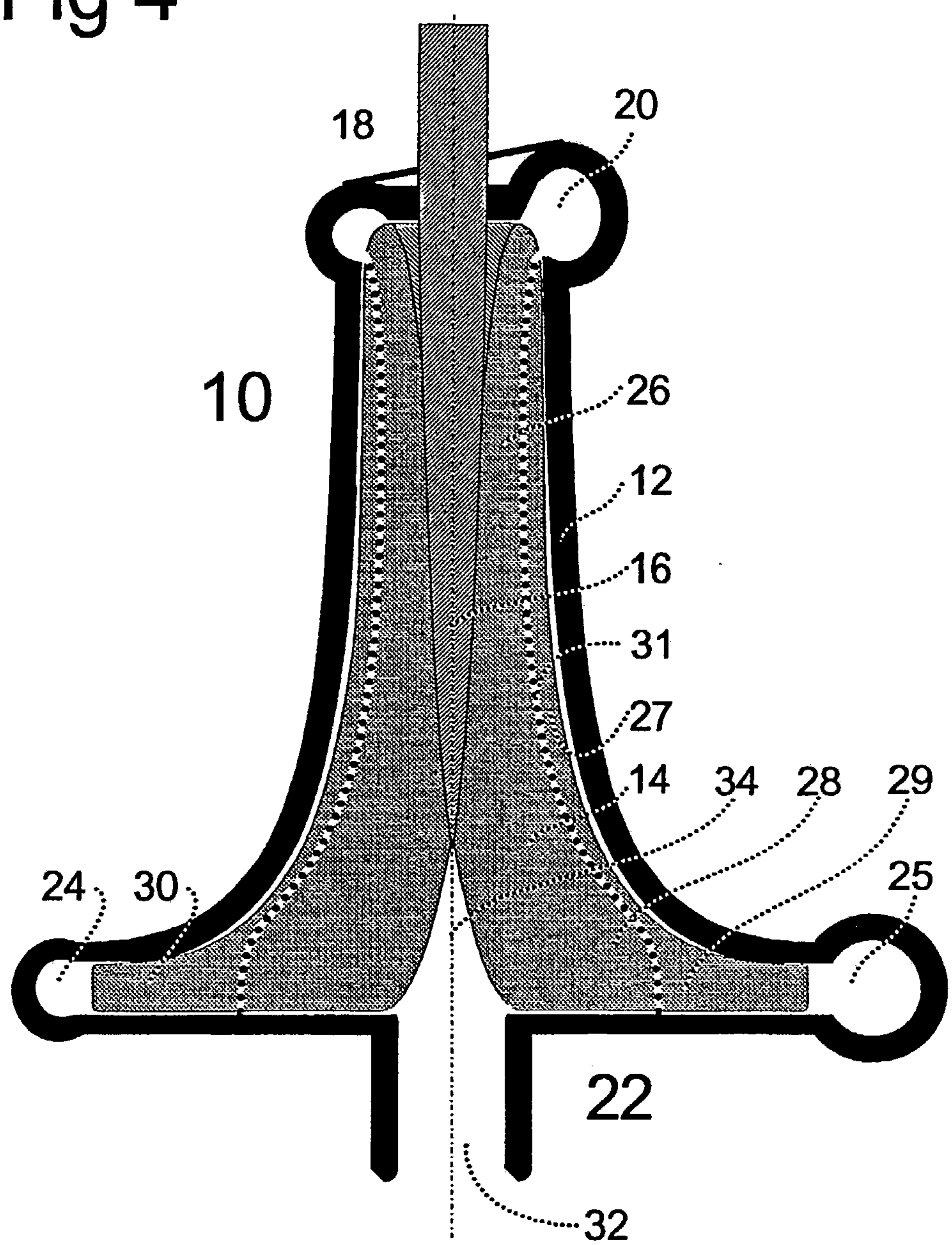


Fig 5

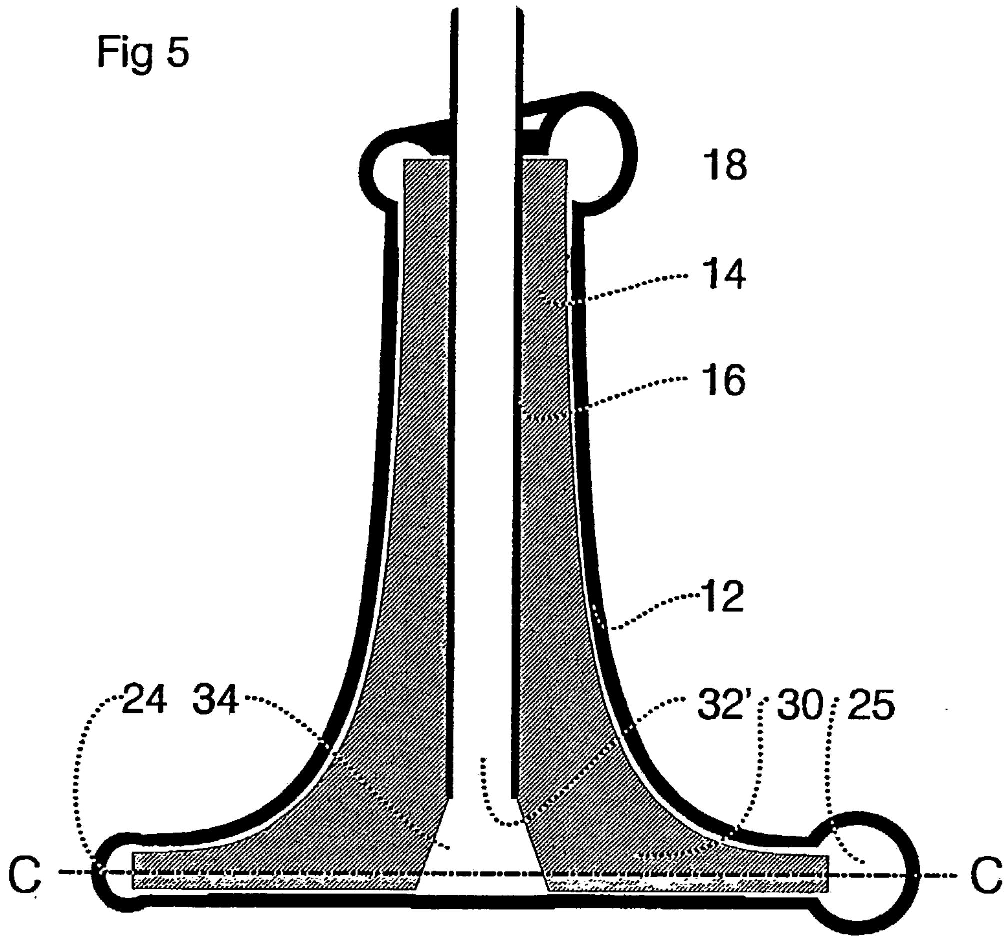
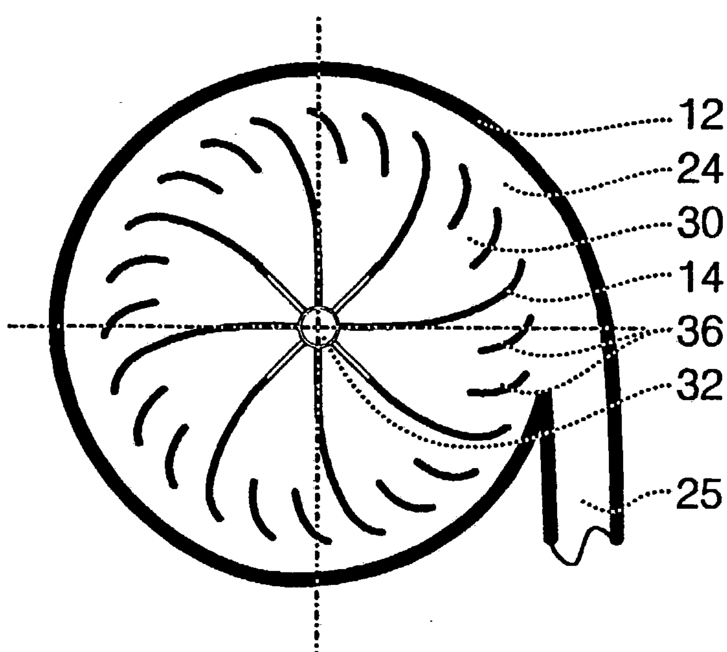


Fig 6



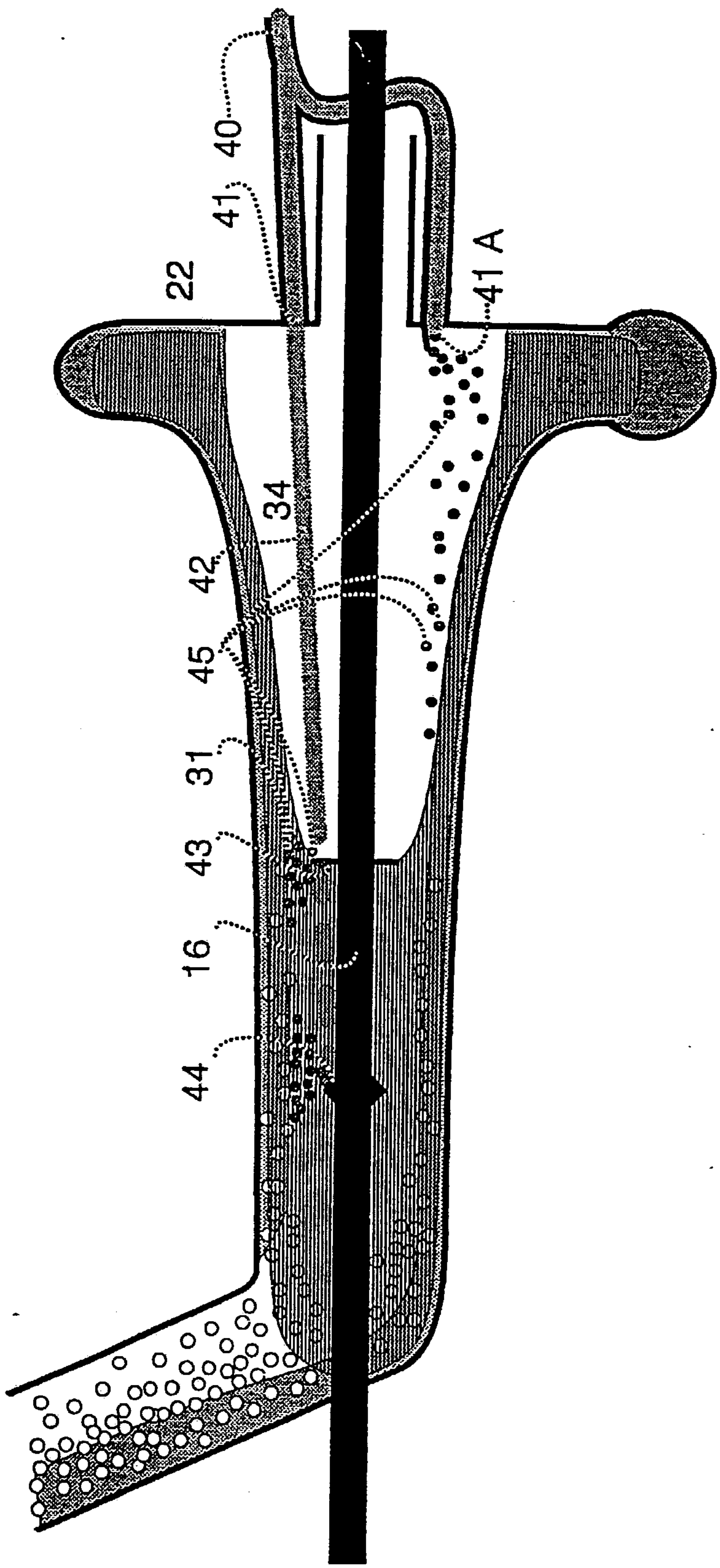


Fig 7

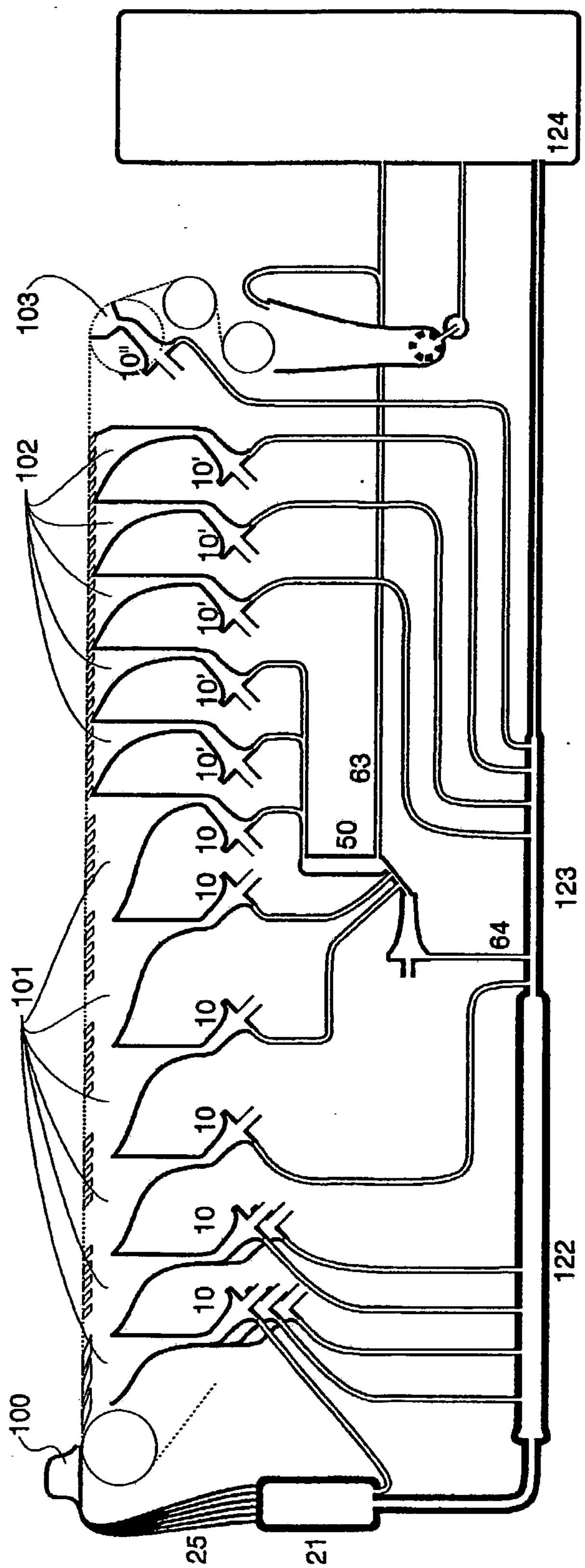

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Fig 8

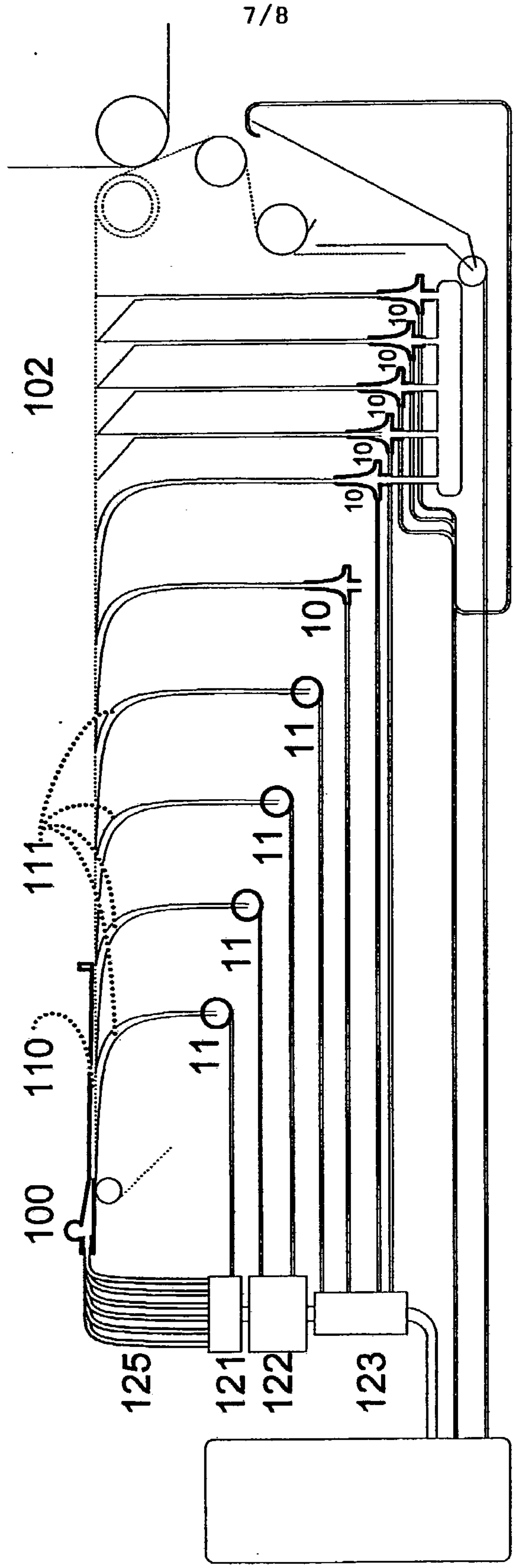
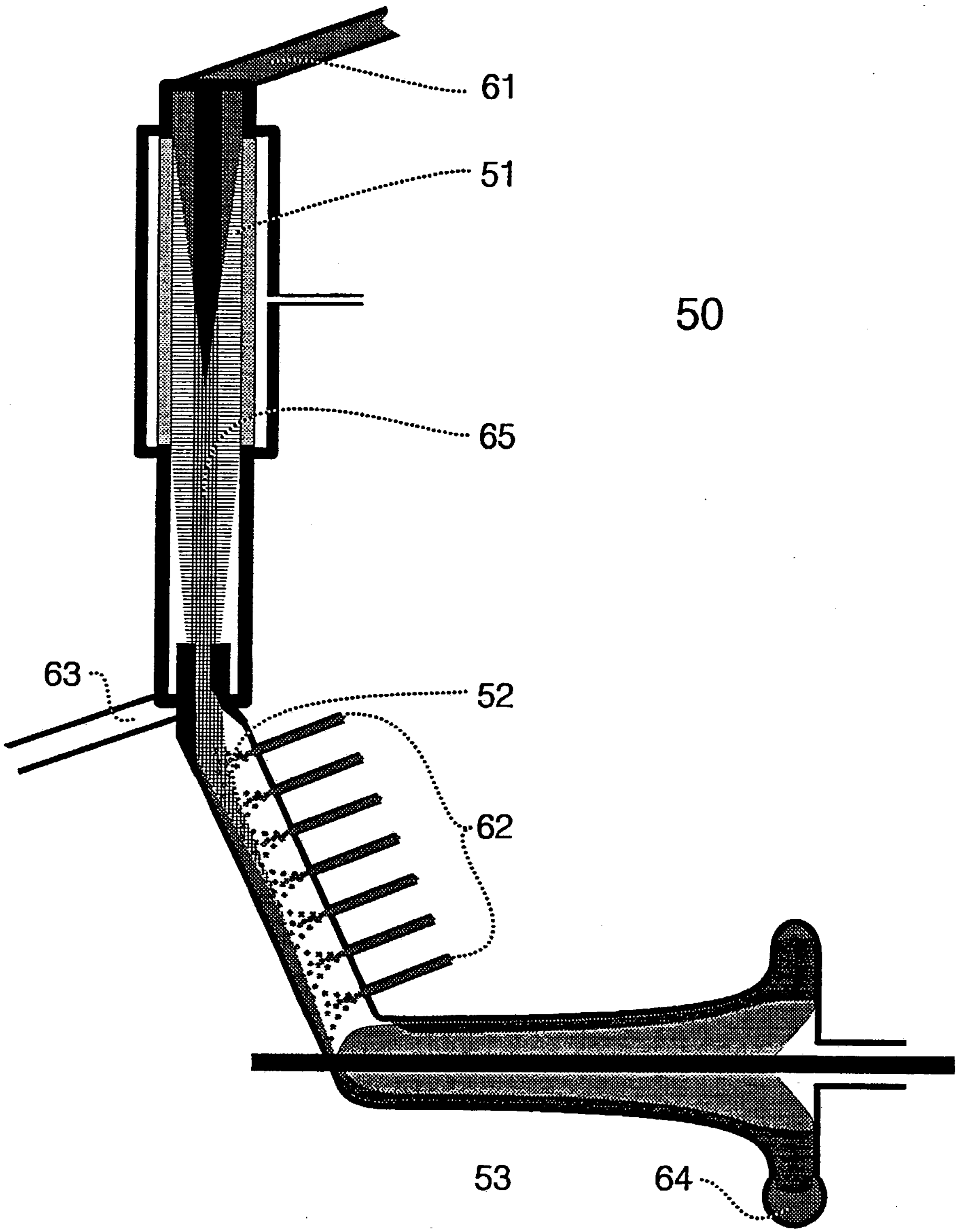


Fig 9

Fig 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 93/00212

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: B01D 19/00, D21D 5/26
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: B01D, D21D, F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5039320 (RONNY HÖGLUND ET AL), 13 August 1991 (13.08.91), column 2, line 44 - column 3, line 25, figures 1,2, abstract --	1,11
A	WO, A1, 9013344 (A. AHLSTROM CORPORATION), 15 November 1990 (15.11.90), figure 1, abstract --	1,11
A	EP, A2, 0330387 (A. AHLSTRÖM CORPORATION), 30 August 1989 (30.08.89), column 10, line 25 - column 11, line 25, figure 7 --	1,11

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 1993	24 -08- 1993
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Johan von Döbeln Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 93/00212

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	WO, A1, 9301875 (A. AHLSTROM CORPORATION), 4 February 1993 (04.02.93), claims 1,10, abstract	1,11

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INTERNATIONAL SEARCH REPORT
Information on patent family members

02/07/93

International application No.
PCT/FI 93/00212

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		FR-A- 2645184	05/10/90
		JP-A- 2269887	05/11/90
		SE-B,C- 467466	20/07/92
		SE-A- 8901082	30/09/90
		US-A- 5209641	11/05/93
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		EP-A- 0397308	14/11/90
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WO-A1- 9301875	04/02/93	NONE	